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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In Re Application of Yamazaki et al. Serial No.: 09/685,698 Filed: October 10, 2000 For: EL Display Device And Method Of Manufacturing The Same Art Unit: 2813 Examiner: Laura M. Schillinger	I hereby certify that this correspondence is being deposited with the United States Postal Service as first class mail in an envelope addressed to: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450 on December 12, 2005 (Date of Deposit) Shannon Wallace Name of applicant, assignee, or Registered Rep. Shannon Wallace 12/12/05 Signature Date

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TRANSMITTAL OF ENGLISH TRANSLATION OF PRIORITY DOCUMENT

Sir:

In response to the Final Rejection dated July 12, 2005, Applicants are submitting herewith an English translation of the priority document.

The present application claims the benefit under 35 USC §119 of JP 11-290356 filed October 12, 1999 in Japan. A certified copy of this priority application was filed with the present application on October 10, 2000. Applicants are now filing an English language translation of JP 11-290356.

Conclusion

Accordingly, it is respectfully requested that the present application be given the benefit of the October 12, 1999 priority date.

If any fee is due for this submission, please charge our deposit account 50/1039.

Favorable reconsideration is earnestly solicited.

Respectfully submitted,

Date: December 12, 2005

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[List of Attachment]

[Attachment] Specification 1

[Attachment] Drawing 1

[Attachment] Abstract 1

[Proof] required

[Document Name] Specification

[Title of the Invention] EL DISPLAY DEVICE AND A METHOD OF MANUFACTURING THE SAME

[Scope of Claims]

[Claim 1]

An EL display device comprising:

a plurality of gate wirings,

a plurality of source wirings orthogonal to the plurality of gate wirings,

a TFT formed in a region surrounded by the plurality of gate wirings and the plurality of source wirings; and

a pixel portion including an EL element electrically connected to the TFT,

characterized in that

the pixel portion comprises a pixel row in which a stripe shape light emitting layer emitting red color light is formed, a pixel row in which a stripe shape light emitting layer emitting green color light is formed, and a pixel row in which a stripe shape light emitting layer emitting blue color light is formed when the pixel portion is viewed as an assembly of a plurality of pixel rows partitioned by the plurality of gate wirings.

[Claim 2]

An EL display device comprising:

a plurality of gate wirings,

a plurality of source wirings orthogonal to the plurality of gate

wirings,

a TFT formed in a region surrounded by the plurality of gate wirings and the plurality of source wirings; and

a pixel portion including an EL element electrically connected to the TFT,

characterized in that

the pixel portion comprises a pixel row in which a stripe shape light emitting layer emitting red color light is formed, a pixel row in which a stripe shape light emitting layer emitting green color light is formed, and a pixel row in which a stripe shape light emitting layer emitting blue color light is formed when the pixel portion is viewed as an assembly of a plurality of pixel rows partitioned by the plurality of source wirings.

[Claim 3]

An EL display device comprising:

a plurality of gate wirings,

a plurality of source wirings orthogonal to the plurality of gate wirings,

a TFT formed in a region surrounded by the plurality of gate wirings and the plurality of source wirings; and

a pixel portion including an EL element electrically connected to the TFT,

characterized in that

the pixel portion is partitioned into a plurarity of pixel rows by a stripe shape bank provided above the plurality of gate wirings, and

the pixel portion comprises a pixel row in which a stripe shape light emitting layer emitting red color light is formed, a pixel row in which a stripe shape light emitting layer emitting green color light is formed, and a pixel row in which a stripe shape light emitting layer emitting blue color light is formed.

[Claim 4]

An EL display device comprising:

a plurality of gate wirings,

a plurality of source wirings orthogonal to the plurality of gate wirings,

a TFT formed in a region surrounded by the plurality of gate wirings and the plurality of source wirings; and

a pixel portion including an EL element electrically connected to the TFT,

characterized in that

the pixel portion is partitioned into a plurarity of pixel rows by a stripe shape bank provided the plurality of source wirings, and

the pixel portion comprises a pixel row in which a stripe shape light emitting layer emitting red color light is formed, a pixel row in which a stripe shape light emitting layer emitting green color light is formed, and a pixel row in which a stripe shape light emitting layer emitting blue color light is formed.

[Claim 5]

An EL display device comprising:

a pluratiy of cathodes arranged in stripes,

a plurality of anodes provided in stripes so as to be orthogonal to the

plurality of cathodes; and

a pixel portion including a light emitting layer provided between the plurality of cathodes and the plurality of anodes,

characterized in that

the pixel portion comprises a pixel row in which a stripe shape light emitting layer emitting red color light is formed, a pixel row in which a stripe shape light emitting layer emitting green color light is formed, and a pixel row in which a stripe shape light emitting layer emitting blue color light is formed when the pixel portion is viewed as an assembly of a plurality of pixel rows partitioned by the plurality of cathodes.

[Claim 6]

An EL display device comprising:

a pluratiy of cathodes arranged in stripes,

a plurality of anodes provided in stripes so as to be orthogonal to the plurality of cathodes; and

a pixel portion including a light emitting layer provided between the plurality of cathodes and the plurality of anodes,

characterized in that

the pixel portion is partitioned into a plurarity of pixel rows by a stripe shape bank provided along the plurality of cathodes between the plurality of the cathodes, and

the pixel portion comprisies a pixel row in which a stripe shape light emitting layer emitting red color light is formed, a pixel row in which a stripe shape light emitting layer emitting green color light is formed, and a pixel row in which a stripe shape light emitting layer emitting blue color light is formed.

[Claim 7]

An EL display device according to any one of claims 1 to 6, characterized in that the light emitting layer emitting red color light, the light emitting layer emitting green color light, and the light emitting layer emitting blue color light are polymer organic EL materials.

[Claim 8]

An electronic equipment, characterized in that the EL display device according to any one of claims 1 to 7 is used as a display portion.

[Claim 9]

A method of manufacturing an EL display device comprising:

a plurality of gate wirings,

a plurality of source wirings orthogonal to the plurality of gate wirings,

a TFT formed in a region surrounded by the plurality of gate wirings and the plurality of source wirings; and

a pixel portion including an EL element electrically connected to the TFT,

characterized by including the step of forming

a stripe shape light emitting layer emitting red color light, a stripe shape light emitting layer emitting green color light, and a stripe shape light emitting layer emitting blue color light on different pixel rows, respectively when the pixel portion is viewed as an assembly of a plurality of pixel rows partitioned by the plurality of gate wirings.

[Claim 10]

A method of manufacturing an EL display device comprising:

a plurality of gate wirings,

a plurality of source wirings orthogonal to the plurality of gate wirings,

a TFT formed in a region surrounded by the plurality of gate wirings and the plurality of source wirings; and

a pixel portion including an EL element electrically connected to the TFT,

characterized by including the step of forming

a stripe shape light emitting layer emitting red color light, a stripe shape light emitting layer emitting green color light, and a stripe shape light emitting layer emitting blue color light on different pixel rows, respectively when the pixel portion is viewed as an assembly of a plurality of pixel rows partitioned by the plurality of source wirings.

[Claim 11]

A method of manufacturing an EL display device comprising:

a plurality of gate wirings,

a plurality of source wirings orthogonal to the plurality of gate wirings,

a TFT formed in a region surrounded by the plurality of gate wirings and the plurality of source wirings; and

a pixel portion including an EL element electrically connected to the TFT,

characterized by including the steps of:

forming a stripe shape bank above the plurality of gate wirings and partitioning the pixel portion into plurality of pixel rows, and

forming a stripe shape light emitting layer emitting red color light, a stripe shape light emitting layer emitting green color light, and a stripe shape light emitting layer emitting blue color light on different pixel rows, respectively.

[Claim 12]

A method of manufacturing an EL display device comprising:

a plurality of gate wirings,

a plurality of source wirings orthogonal to the plurality of gate wirings,

a TFT formed in a region surrounded by the plurality of gate wirings and the plurality of source wirings; and

a pixel portion including an EL element electrically connected to the TFT,

characterized by including the steps of:

forming a stripe shape bank above the plurality of source wirings and partitioning the pixel portion into plurality of pixel rows, and

forming a stripe shape light emitting layer emitting red color light, a stripe shape light emitting layer emitting green color light, and a stripe shape light emitting layer emitting blue color light on different pixel rows, respectively.

[Claim 13]

A method of manufacturing an EL display device comprising:

a pluratiy of cathodes arranged in stripes,

a plurality of anodes provided in stripes so as to be orthogonal to the plurality of cathodes; and

a pixel portion including a light emitting layer provided between the

plurality of cathodes and the plurality of anodes,

characterized by including the step of forming

a stripe shape light emitting layer emitting red color light, a stripe shape light emitting layer emitting green color light, and a stripe shape light emitting layer emitting blue color light on different pixel rows, respectively when the pixel portion is viewed as an assembly of plurality of pixel rows partitioned by the plurality of cathodes.

[Claim 14]

A method of manufacturing an EL display device comprising:

a plurality of cathodes arranged in stripes,

a plurality of anodes provided in stripes so as to be orthogonal to the plurality of cathodes; and

a pixel portion including a light emitting layer provided between the plurality of cathodes and the plurality of anodes,

characterized by including the steps of:

forming a stripe shape bank in space between the plurality of cathodes and the pixel portion is partitioned into plurality of pixel rows, and

forming a stripe shape light emitting layer emitting red color light, a stripe shape light emitting layer emitting green color light, and a stripe shape light emitting layer emitting blue color light on different pixel rows, respectively.

[Claim 15]

A method of manufacturing an EL display device according to any one of claims 9 to 14, characterized in that the stripe shape light emitting layer emitting red color light, the stripe shape light emitting layer emitting green color light, and the stripe shape light emitting layer emitting blue color light are formed by using a polymer

organic EL material.

[Claim 16]

A method of manufacturing an EL display device according to any one of claims 9 to 14,

characterized in that

the stripe shape light emitting layer emitting red color light, the stripe shape light emitting layer emitting green color light, and the stripe shape light emitting layer emitting blue color light are formed by

discharging a red light emitting layer application liquid for a light emitting layer emitting red color light, a green light emitting layer application liquid for a light emitting layer emitting green color light, and a blue light emitting layer application liquid for a light emitting layer emitting blue color light at the same time from separate nozzles, respectively, and

performing heat treatment to the discharged red light emitting layer application liquid, green light emitting layer application liquid, and blue light emitting layer application liquid.

[Claim 17]

A method of manufacturing an EL display device according to any one of claims 9 to 14,

characterized in that

at least one of the stripe shape light emitting layer emitting red color light, the stripe shape light emitting layer emitting green color light, and the stripe shape light emitting layer emitting blue color light is formed by performing heat treatment to an application liquid discharged from a nozzle, and

at least one of the stripe shape light emitting layer emitting red color light, the stripe shape light emitting layer emitting green color light, and the stripe shape light emitting layer emitting blue color light is formed by a spin coat method, a printing method, or a deposition method.

[Detailed Description of the Invention]

[0001]

[Technical Field to which the Invention pertains]

The present invention relates to an EL display device comprising an EL element which is constructed of an anode, a cathode, and a light emitting organic material capable of obtaining EL (Electro Luminescence) (hereinafter referred to as organic EL material) interposed between the anode and the cathode, and which is formed on a substrate, and relates to a method of manufacturing an electronic device having the EL display device as a display portion (a display or a display monitor). It is to be noted that the above-mentioned EL display device is also referred to as OLED (Organic Light Emitting Diodes).

[0002]

[Prior Art]

In recent years, the development of a display device (EL display device) employing an EL element as a self-light emitting element that utilizes the EL phenomenon of a light emitting organic material is proceeding. Since the EL display device is a self-light emitting type, the EL display does not need a backlight such as the liquid crystal display device. Furthermore, because the viewing angle of EL display devices is wider, the display is perceived as a prospective display portion of mobile

equipment for use outdoors.

[0003]

There are two types of EL display devices, the passive type (simple matrix type) and the active type (active matrix type). Developments for both types of EL display devices have been actively performed. In particular, the active matrix EL display device is currently attracting much attention. Researches have been made on low molecular organic EL materials and high molecular organic EL materials (organic polymer EL materials) as to organic EL materials for forming a light emitting layer which can be regarded as the core of the EL element. Organic polymer EL materials are receiving much attention since the organic polymer EL materials are easier to deal with than low molecular organic EL materials and have high heat resistant characteristics.

[0004]

As a film deposition method of organic polymer EL materials, the ink-jet method proposed by Seiko Epson, Co. Ltd. is considered a favorable method. Japanese Patent Application Laid-open No. Hei 10-12377, Japanese Patent Application Laid-open No. Hei 10-153967, and Japanese Patent Application Laid-open No. Hei 11-54270 etc. may be referred to regarding this technique.

[0005]

However, in the ink-jet method, an organic polymer EL material is sprayed on the application surface. Hence, if the distance between the application surface and the nozzle of the ink-jet head is not set appropriately, drops of solution will be shot to parts that the application is not necessary, resulting in the occurrence of a problem what is known as an aviation curve. Note that details regarding the aviation curve are

disclosed in the above-mentioned Japanese Patent Application Laid-open No. Hei 11-54270, in which 50 μm or more of slip occurs from the positional target of shot.

[0006]

[Problems to be Solved by the Invention]

The present invention has been made in view of the above problem, and an object thereof is to provide a high throughput film deposition means for film depositing an organic EL material made of polymer accurately and without any positional shift. Another object of the present invention is to provide an EL display device employing such means and a method of manufacturing the same. Still further, another object of the present invention is to provide electronic equipment having such EL display devices as its display portion.

[0007]

[Means for Solving the Problems]

In order to achieve the above objects, the present invention is characterized in that red, green, and blue light emitting layers are formed into stripe shapes by using a dispenser-like thin film deposition apparatus. It is to be noted that stripe shapes include a long and narrow rectangle having an aspect ratio of 2 or greater, and a long and narrow ellipse having the ratio of its major axis and minor axis equal to 2 or greater. The thin film deposition apparatus of the present invention is shown in Fig.1.

[0008]

Fig. 1(A) is a diagram schematically showing the state of the film deposition of an organic EL material made of π conjugate-based polymer when the present invention is implemented. In Fig. 1(A), reference numeral 110 is a substrate, and a pixel portion 111, a source side driver circuit 112, and a gate side driver circuit 113, are formed of

TFTs on the substrate 110. A region surrounded by a plurality of source wirings connected to the source side driver circuit 112 and a plurality of gate wirings connected to the gate side driver circuit 113 is a pixel. A TFT and an EL element electrically connected to the TFT are formed in the pixel. Thus, the pixel portion 111 is formed of such pixels arranged in matrix.

[0009]

Here, reference numeral 114a denotes a mixture of an organic EL material that emits red light and a solvent (hereinafter referred to as a red light emitting layer application liquid); 114b denotes a mixture of an organic EL material that emits green light and a solvent (hereinafter referred to as a green light emitting layer application liquid); and 114c denotes a mixture of an organic EL material that emits blue light and a solvent (hereinafter referred to as a blue light emitting layer application liquid). Note that these organic EL materials have a method of directly dissolving a polymerized material into the solvent for application, or a method of performing thermal polymerization to a material which is formed by dissolving monomer in a solvent and then by performing film deposition, to form a polymer. Either of the methods can be used in the present invention. An example of applying an organic EL material processed into a polymer and dissolved in a solvent is shown here.

[0010]

In the case of the present invention, the red light emitting layer application liquid 114a, the green light emitting layer application liquid 114b, and the blue light emitting layer application liquid 114c are separately discharged from the thin film deposition apparatus and applied in the direction indicated by the arrow. In other words, in a pixel row that will emit red light, a pixel row that will emit green light, and

a pixel row that will emit blue light, stripe shape light emitting layers (strictly a precursor of a light emitting layer) are simultaneously formed.

[0011]

Note that the pixel row referred here indicates a row of pixel partitioned by a bank 121 that is formed on the upper part of the source wiring. That is, a row composed of a plurality of pixels lined up in series along the source wiring is called a pixel row. A case where the bank 121 is formed on the upper part of the source wiring was described here, but the bank 121 may also be provided on the upper part of the gate wiring. In this case, a row composed of a plurality of pixels lined up in series along the gate wiring is called a pixel row.

[0012]

Accordingly, the pixel portion 111 can be viewed as an assembly of a plurality of pixel rows partitioned by the stripe shape bank provided on the upper part of the plurality of source wirings or gate wirings. When the pixel portion is viewed as the above, it can also be said that the pixel portion 111 is made up of a pixel row in which a stripe shape light emitting layer emitting red color light is formed, a pixel row in which a stripe shape light emitting layer emitting green color light is formed, and a pixel row in which a stripe shape light emitting layer emitting blue color light is formed.

[0013]

Further, since the above-stated stripe shape bank is provided above the plurality of source wirings or plurality of gate wirings, substantially, the pixel portion 111 can also be viewed as an assembly of a plurality of pixel rows partitioned by the source wirings or the gate wirings.

[0014]

Next, Fig. 1(B) shows the state of a head portion (may also be referred as a discharge portion) of the thin film deposition apparatus when the application process illustrated in Fig. 1(A) is performed.

[0015]

Reference numeral 115 denotes a head portion of the thin film deposition apparatus with a nozzle 116a for the red color, a nozzle 116b for the green color, and a nozzle 116c for the blue color attached thereto. Furthermore, the red light emitting layer application liquid 114a, the green light emitting layer application liquid 114b, and the blue light emitting layer application liquid 114c are stored inside the respective nozzles. Inert gas with which a pipe 117 is filled up is pressurized to discharge these application liquids to the pixel portion 111. The application process illustrated in Fig. 1(A) is performed by scanning the head portion 115 toward the front along a perpendicular direction of a defined space.

[0016]

Note that the head portion is stated as being scanned throughout the present specification. In practice, the substrate is moved in a vertical or horizontal direction by the X-Y stage. Thus, the head portion is relatively scanned in a vertical or horizontal direction on the substrate. As a matter of course, the substrate can be fixed so that the head portion itself conducts the scanning. However, from the viewpoint of stability, a method of moving the substrate is preferred.

[0017]

Fig. 1(C) is a diagram showing an enlarged view of the vicinity of the discharge portion denoted by the reference numeral 118. The pixel portion 111 formed on the substrate 110 is an assembly of a plurality of pixels composed of a

plurality of TFTs 119a to 119c and a plurality of pixel electrodes 120a to 120c. In Fig. 1(B), when the nozzles 116a to 116c are pressurized by inert gas, application liquids 114a to 114c will be discharged from the nozzles 116a to 116c due to this pressure.

[0018]

Note that the bank 121 formed of a resin material is provided in the space between adjacent pixels to prevent the application liquid from mixing into a space between pixels. In this structure, the width of the bank 121 (determined by the resolution of photolithography) is made to be narrow so that the integration degree of the pixel portion is increased, and therefore, high definition images can be attained. It is particularly effective in the case in which the viscosity of the application liquids is 1 to 30 cp.

[0019]

However, if the viscosity of the application liquid is 30 cp or more, or if the application liquid is in the form of sol or gel, then it is possible to omit the bank from the structure. In other words, as long as the angle of contact between the application liquid after being applied and the application surface is large enough, the application liquid will not spread out more than necessary. Therefore, the provision of the bank for preventing the application liquid from spreading out more than necessary is not required. In this case, the final shape of the light emitting layers will be formed into an oval shape (a long and narrow ellipse wherein the ratio of the major axis and the minor axis is 2 or greater), typically a long and narrow ellipse extending from one end of the pixel portion to the other end thereof.

[0020]

As resin materials for forming the bank 121, acrylic, polyimide, polyamide,

and polyimede amide can be used. When carbon or black pigment or the like is provided in these resin materials in advance to make the resin materials black, then it is possible to use the bank 121 as a light shielding film between pixels.

[0021]

In addition, by attaching a sensor that employs a light reflector near the tip of any one of the nozzles 116a, 116b, and 116c, the distance between the application surface and the nozzles may be regulated so as to maintain a fixed distance at all times. Furthermore, provision of a mechanism for regulating the gap among the nozzles 116a to 116c in correspondence with the pixel pitch (distance between pixels) allows the nozzles to be applied to EL display devices having any pixel pitch.

[0022]

Thus, the application liquids 114a to 114c discharged from the nozzles 116a to 116c are applied so as to cover the respective pixel electrodes 120a to 120c. After applying the application liquids 114a to 114c, heat treatment (bake treatment or burning treatment) is performed in vacuum to volatilize the organic solvent contained in the application liquids 114a to 114c, thereby forming the light emitting layers made of an organic EL material. Therefore, an organic solvent that will volatilize under a temperature lower than the glass transition temperature (Tg) of the organic EL material is used. Further, the film thickness of the light emitting layers that are finally formed is determined by the viscosity of the organic EL material. In this case, although the viscosity may be regulated by the choice of the organic solvent or a dopant, it is preferable that the viscosity be between 1 and 50 cp (preferably between 5 and 20 cp).

[0023]

If there are many impurities likely to become crystal nuclei in the organic EL

material, the possibility of crystallizing the organic EL material becomes high when the organic solvent is volatilized. When the organic EL material is crystallized, the efficiency of light emission drops, and therefore is unfavorable. It is desirable that, as much as possible, impurities are not contained in the organic EL material.

[0024]

To reduce the impurities, the solvent and the organic EL material are intensively refined, and it is important to keep the environment as clean as possible when mixing the solvent and the organic EL material. For the refinement of the solvent or the organic EL material, it is preferable that techniques such as evaporation, sublimation, filtration, recrystallization, re-sedimentation, chromatography, or dialysis be performed repetitiously. It is desirable to reduce ultimately impurities such as a metal element and an alkaline metal element to 0.1 ppm or less (preferably 0.01 ppm or less).

[0025]

In addition, it is preferable that sufficient attention be paid to the atmosphere in applying the application liquid containing an organic EL material formed by the thin film deposition apparatus illustrated in Fig. 1. To be more specific, it is desirable that the film deposition of the above-mentioned organic EL material is performed in a clean booth filled with inert gas such as nitrogen and inside a glove box.

[0026]

By using such as the thin film deposition apparatus, the three types of light emitting layers emitting red, green, and blue light can be formed at the same time. Consequently, light-emitting layers made of an organic polymer EL material can be formed at a high throughput. In addition, being different from the ink-jet method, the

method of the present invention is capable of applying the application liquids in stripes to a pixel row without any intervals, resulting in an extremely high throughput.

[0027]

[Embodiment Modes of the Invention]

Embodiment modes of the present invention will be described with reference to Figs. 2, 3(A) and 3(B). Fig. 2 shows a cross-sectional view of a pixel portion in an EL display device in accordance with the present invention. Fig. 3(A) shows a top view of the pixel portion, and Fig. 3(B) shows the circuit configuration thereof. In an actual structure, pixels are arranged in a plurality of lines to be in matrix, thereby forming a pixel portion (image display portion). Fig. 2 illustrates a cross-sectional view taken along the line A-A' in Fig. 3(A). Accordingly, the same components are commonly designated by the same reference numerals in Figs 2, 3(A) and 3(B), and it will be advantageous for understanding the structure to refer to both of the figures. In addition, the two pixels illustrated in the top view of Fig. 3(A) have the same structure.

[0028]

In Fig. 2, reference numeral 11 denotes a substrate, and 12 denotes an insulating film to be a base (hereinafter referred to as the base film). As the substrate 11, a glass substrate, a glass ceramic substrate, a quartz substrate, a silicon substrate, a ceramic substrate, a metal substrate, or a plastic substrate (including a plastic film) can be used.

[0029]

In addition, the base film 12 is especially advantageous for using a substrate including mobile ions or a substrate having conductivity. However, the base film 12 may not be provided for a quartz substrate. As the base film 12, an insulating film

containing silicon (silicon) may be used. In the present specification, the "insulating film containing silicon" refers to an insulating film containing silicon and oxygen or nitrogen at a predetermined ratio, and more specifically, a silicon oxide film, a silicon nitride film, or a silicon oxide nitride film (represented as SiOxNy).

[0030]

It is advantageous to provide the base film 12 with a heat radiation function to dissipate heat generated in a TFT in order to prevent a TFT or an EL element from deteriorating. The heat radiation function can be provided by any known material.

[0031]

Here, two TFTs are provided in one pixel. A TFT 201 functions as a switching element (hereinafter referred to as the switching TFT), and a TFT 202 functions as a current controlling element for controlling an amount of current to flow through the EL element (hereinafter referred to as the current control TFT). Both of the TFTs 201 and 202 are made of the n-channel TFT.

[0032]

Since the n-channel TFT has a field effect mobility higher than that of the p-channel TFT, the n-channel TFT can operate at higher speed and accept a large amount of current. Furthermore, a current of the same amount can flow through the n-channel TFT of which size is smaller as compared to the p-channel TFT. Accordingly, it is preferable to use the n-channel TFT as the current control TFT since an effective surface area of the display portion is increased.

[0033]

The p-channel TFT has advantages in which the injection of hot carriers becomes hardly a problem and an OFF current value is small. Thus, it has been already

reported the p-channel TFT is used as the switching TFT or the current control TFT. However, in the present invention, the disadvantages in connection with the injection of hot carriers and a small OFF current value can be overcome even in the n-channel TFT by providing the arrangement of LDD regions. Thus, it is also possible that all of the TFTs in the pixel are made of the n-channel TFTs.

[0034]

However, the present invention is not limited to the case where the switching TFT and the current control TFT are made of the n-channel TFTs. It is possible to use the p-channel TFT as both or either of the switching TFT and the current control TFT.

[0035]

The switching TFT 201 is formed to have a source region 13, a drain region 14, an active layer including LDD regions 15a to 15d, a high concentration impurity region 16, and channel forming regions 17a and 17b, a gate insulating film 18, gate electrodes 19a and 19b, a first interlayer insulating film 20, a source wiring 21, and a drain wiring 22.

[0036]

In addition, as shown in Figs. 3(A) and 3(B), the gate electrodes 19a and 19b are electrically connected to each other by means of a gate wiring 211 which is made of a different material (a material having a lower resistivity than the gate electrodes 19a and 19b), thereby forming a double-gate structure. It is of course possible to employ, not only the double-gate structure, but also the so-called multi-gate structure (a structure including an active layer, which contains two or more channel forming regions, connected in series) such as a triple-gate structure. The multi-gate structure is significantly advantageous for decreasing OFF current value. In accordance with the

present invention, a switching element having a low OFF current value can be realized by providing the switching element 201 in the pixel with the multi-gate structure.

[0037]

In addition, the active layer is formed of a semiconductor film that includes a crystalline structure. This is, a single crystalline semiconductor film, a polycrystalline semiconductor film, or a microcrystalline semiconductor film may be used. The gate insulating film 18 may be formed of an insulating film containing silicon. Furthermore, any kind of conductive films can be used as the gate electrode, the source wiring, or the drain wiring.

[0038]

Furthermore, in the switching TFT 201, the LDD regions 15a to 15d are disposed so as not to overlap with the gate electrodes 17a and 17b with the gate insulating film 18 interposed therebetween. Such a structure is significantly advantageous for reducing an OFF current value.

[0039]

For reducing the OFF current value, it is further preferable to provide an offset region (a region which is made of a semiconductor layer having the same composition as the channel forming regions and that a gate voltage is not applied thereto) between the channel forming regions and the LDD regions. In addition, in the case of the multi-gate structure having two or more gate electrodes, the high concentration impurity region disposed between the channel forming regions is effective for reducing the OFF current value.

[0040]

As mentioned above, the OFF current value can be sufficiently lowered if the

multi-gate structure TFT is used as the switching TFT 201 of the pixel. Therefore, an advantage of capable of maintaining the gate voltage of the current control TFT until the next writing period can be attained without providing a condenser such as the one of Fig. 2 disclosed in Japanese Patent Application Laid-open No. Hei 10-189252. As a matter of course, the condenser may be provided.

[0041]

Then, the current control TFT 202 is formed to have a source region 31, a drain region 32, an active layer including an LDD region 33 and a channel forming region 34, a gate insulating film 18, a gate electrode 35, a first interlayer insulating film 20, a source wiring 36, and a drain wiring 37. Although the gate electrode 35 has the single-gate structure, it may have the multi-gate structure.

[0042]

As shown in Fig. 2, a drain of the switching TFT 201 is connected to a gate of the current control TFT 202. More specifically, the gate electrode 35 of the current control TFT 202 is electrically connected to the drain region 14 of the switching TFT 201 through the drain wiring 22. Furthermore, the source wiring 36 is connected to a power supply line 212 (see Fig. 3(A)).

[0043]

The current control TFT 202 is an element intended to control an amount of current to be injected into the EL element 203. However, considering a deterioration of the EL element, it is not preferable to allow a large amount of current to flow. Accordingly, in order to prevent excessive current from flowing through the current control TFT 202, the channel length (L) thereof is preferably designed to be long. Desirably, the channel length (L) is designed to be 0.5 to 2 μm (preferably, 1 to 1.5 μm)

long per pixel.

[0044]

In the view of the above-mentioned description, as shown in Fig. 9, the channel length L1 (where L1 = L1a + L1b) and the channel width W1 of the switching TFT, and the channel length L2 and the channel width W2 of the current control TFT are preferably set as follows: W1 is in the range from 0.1 to 5 μm (typically, 0.5 to 2 μm); W2 is in the range from 0.5 to 10 μm (typically, 2 to 5 μm); L1 is in the range from 0.2 to 18 μm (typically, 2 to 15 μm); and L2 is in the range from 1 to 50 μm (typically, 10 to 30 μm). However, the present invention is not limited to the above-mentioned values.

[0045]

The length (width) of the LDD regions to be formed in the switching TFT 201 is set in the range from 0.5 to 3.5 μm, typically in the range from 2.0 to 2.5 μm.

[0046]

The EL display device as shown in Fig. 1 has features in which the LDD region 33 is provided between the drain region 32 and the channel forming region 34 in the current control TFT 202, and the LDD region 33 has a portion overlapping with the gate electrode 35 and a portion not overlapping with the gate electrode 35 with the gate insulating film 18 interposed therebetween.

[0047]

In order to supply a current for making the EL element 204 emit light, it is preferable for the current control TFT 202 that steps be taken against deterioration due to hot carrier injection. Further, in the case of displaying black color, the current control TFT 202 is made to be the off state. However, clear black display cannot be

performed and the decline of the contrast will be led when the OFF current value is high. Therefore, it is preferable that the OFF current value also be suppressed.

[0048]

It is known that a structure of the LDD region overlapping with the gate electrode is effective against the deterioration due to the hot carrier injection. However, when the entire LDD region is overlapped with the gate electrode, the OFF current value is increased. The present applicant solves the hot carrier provision and the OFF current value provision at the same time by providing a novel structure in which a LDD region that is not overlapped with the gate electrode is provided in series.

[0049]

The length of the LDD region, which overlaps with the gate electrode, may be made from 0.1 to 3 μm (preferably between 0.3 and 1.5 μm) at this point. If the length of the LDD region is made to be too long, parasitic capacitance is enlarged, and if the length of the LDD is made to be too short, the effect of preventing the hot carrier becomes weak. Further, in the case of providing an LDD region that does not overlap with the gate electrode, the length of the LDD region may be made from 1.0 to 3.5 μm (preferably between 1.5 and 2.0 μm). If the length is made to be too long, sufficient current cannot flow, and if the length is made to be too short, the effect of reducing the OFF current value becomes weak.

[0050]

In addition, the parasitic capacity is formed in the region where the LDD region overlaps with the gate electrode in the above structure, and therefore, it is preferable that the LDD region be not provided between the source region 31 and the channel forming region 34. The carrier (electrons in this case) flow direction is always

the same in the current control TFT 202, and therefore it is sufficient to form the LDD region on only the drain region side.

[0051]

From the viewpoint of increasing a possible amount of current to flow, it is also effective to thicken the film thickness of the active layer (in particular, at the channel forming region) of the current control TFT 202 (preferably in the range from 50 to 100 nm, and more preferably in the range from 60 to 80 nm). On the other hand, in the case of the switching TFT 201, from the viewpoint of reducing an OFF current value, it is also effective to thin the film thickness of the active layer (in particular, at the channel forming region) (preferably in the range from 20 to 50 nm, and more preferably in the range from 25 to 40 nm).

[0052]

Next, reference numeral 38 denotes a first passivation film, and the film thickness may be formed to between 10 to 1 μm (preferably between 200 and 500 nm). An insulating film containing silicon (particularly a silicon nitride oxide film or a silicon nitride film is preferred) can be employed as a material. Furthermore, it is effective to form the first passivation film 38 to have a thermal radiation effect.

[0053]

A second interlayer insulating film 39 (leveling film) is formed on the first passivation film 38, and the leveling of a stepped portion that is formed by the TFT is performed. An organic resin film is preferable as the second interlayer insulating film 39, and one such as polyimide, polyamide, acrylic, or BCB (benzocyclobutene) may be used. An inorganic film may be also used, of course, provided sufficient leveling is possible.

[0054]

The leveling of a stepped portion in the TFT by the second interlayer insulating film 39 is extremely important. The EL layer formed afterward is very thin, and therefore there are cases in which poor luminescence is caused by the existence of the stepped portion. It is therefore preferable to perform leveling before forming a pixel electrode so as to be able to form the EL layer on as level a surface as possible.

[0055]

Reference numeral 40 denotes a pixel electrode (EL element cathode) made from a highly reflective conductive film. After opening a contact hole (an opening) in the second interlayer insulating film 39 and in the first passivation film 38, the pixel electrode 40 is formed so as to be connected to the drain wiring 37 of the current control TFT 202 in the formed opening portion. It is preferable to use low resistant conductive films such as aluminum alloy and copper alloy as the pixel electrode 40. As a matter of course, it may also be a laminated structure with other conductive films.

[0056]

A light emitting layer 42 is formed by a device such as the thin film deposition apparatus described in Fig. 1. It is to be noted that although only one pixel is illustrated in the drawing, light emitting layers corresponding to the respective colors R (red), G (green), and B (blue) are simultaneously formed. A polymer material is used for the organic EL material as the light emitting layer. Polymers such as the following can be given as typical polymer materials: polyparaphenylene vinylene (PPV)-based material; polyvinyl carbazole (PVK)-based one; and polyfluorene-based one.

[0057]

Note that there are various types of PPV-based organic EL material. For

example, a molecular formula such as the following has been reported.

(H.Shenk, H.Becker, O.Gelsen, E.Kluge, W.Kreuder and H.Spreitzer, "Polymers for Light Emitting Diodes", Euro Display, Proceedings, 1999, pp. 33-37)

[0058]

[Chemical Formula 1]

[0059]

[Chemical Formula 2]

[0060]

Further, the molecular formula of polyphenylene vinylene disclosed in Japanese Patent Application Laid-open No. 10-92576 can be used. The molecular formula becomes as follows:

[0061]

[Chemical Formula 3]

[0062]

[Chemical Formula 4]

[0063]

Further, as a molecular formula of a PVK-based organic EL material, there is one such as the following.

[0064]

[Chemical Formula 5]

[0065]

The polymer organic EL material can be dissolved in a solvent as a polymer state and then applied, or it can be dissolved in a solvent as a monomer and then

polymerized after application. When applied as a monomer, a polymer precursor is formed at first, and this is polymerized into a polymer by heating within a vacuum.

[0066]

As a specific light emitting layer, a cyano-polyphenylene vinylene may be used for the light emitting layer that emits a red color light; a polyphenylene vinylene for the light emitting layer that emits a green color light; and a polyphenylene vinylene or a polyalkylphenylene for the light emitting layer that emits a blue color light. The film thickness of the light emitting layers may be formed to between 30 and 150 nm (preferably between 40 and 100 nm).

[0067]

However, the above examples are only some examples of organic EL materials that can be used as the light emitting layer of the present invention, and there is absolutely no need to limit to these. In the present invention, a mixture of an organic EL material and a solvent is applied by using the method illustrated in Fig. 1. The solvent is then volatilized, thereby removing the solvent to form a light emitting layer. Therefore, during the volatilization of the solvent, the combinations of any type of organic EL materials that do not exceed the glass transition temperature of the light emitting layer may be used.

[0068]

Chloroform, dichloromethane, γ butyl lactone, butyl cellosolve, or NMP (N-methyl-2-pyrrolidone) are cited as typical solvents. It is also effective to add a dopant for raising the viscosity of the application liquid.

[0069]

Furthermore, when forming the light emitting layer 42, the treatment

atmosphere is a dry atmosphere with as small amount of moisture as possible, desirably, carrying out the formation in an inert gas atmosphere. Degradation of the EL layer is easily caused by the presence of moisture and oxygen. Therefore, when forming the EL layer, it is necessary to eliminate these factors as much as possible. For example, atmospheres such as a dry nitrogen atmosphere and a dry argon atmosphere is preferable. In order to do this, the thin film deposition apparatus of Fig. 1 is installed in a clean booth that is filled with inert gas. It is desirable that the film deposition process of the light emitting layer be carried out in this atmosphere.

[0070]

If the light emitting layer 43 is formed as the above-mentioned, a hole injection layer 43 will be formed next. PEDOT (Polythiophene) or PAni (polyaniline) is used as the hole injection layer 43 in the present invention. Since these materials are water-soluble, the light emitting layer 42 can be formed without dissolving, and its film thickness may be 5 to 30 nm (preferably 10 to 20 nm).

[0071]

An anode 44 made from a transparent conductive film is provided on the hole injection layer 43. In the case of the present embodiment mode, light produced by the light emitting layer 43 is emitted towards the upper side surface (in a direction towards the top of the TFT). Thus, the anode must have light transmitting characteristics. A compound of indium oxide and tin oxide and a compound of indium oxide and zinc oxide can be used as the transparent conductive film. However, since the transparent conductive film is formed after the formation of the light emitting layer and the hole injection layer, which are low in heat resistance, materials which can be formed at as low a temperature as possible are preferable.

[0072]

The EL element 203 is completed at the point the anode 44 is formed. Note that the EL element 203 referred to here designates a capacitor formed of the pixel electrode (cathode) 40, the hole injection layer 42, the light emitting layer 43, and the anode 44. As shown in Fig. 3, since the pixel electrode 40 almost coincides with the surface area of the pixel, the entire pixel functions as the EL element. Accordingly, the utility efficiency of luminescence is extremely high, making it possible to display brighter images.

[0073]

Further, in the present embodiment mode, the pixel electrode 40 is formed so that its structure is that of a cathode. Therefore, light generated by the light emitting layer are all emitted to the anode side. However, contrary to the structure of this EL element, it is also possible to form the pixel electrode so that its structure is that of an anode made of a transparent conductive film. In this case, since light generated by the light emitting layer are also emitted to the anode side, light is observed from the substrate 11 side.

[0074]

In the present embodiment mode, a second passivation film 45 is further provided on the anode 44. As the second passivation film 45, a silicon nitride film or a silicon nitride oxide film is preferable. The purpose of this is to shield the EL element from the outside, and has two meanings of which one is to prevent the organic EL material from deterioration due to oxidation, and the other is to suppress the leakage of gas from the organic EL material. Hence, the reliability of the EL display device can be increased.

[0075]

The EL display device of the present invention has a pixel portion containing a pixel with a structure as shown in Fig. 2, and TFTs having different structures in response to their functions are arranged in the pixel. A switching TFT having a sufficiently low OFF current value, and a current control TFT which is strong with respect to hot carrier injection can be formed within the same pixel, and an EL display device having high reliability and being capable of good image display (high operating performance) can thus be formed.

[0076]

It is to be noted that although the structure of a planar TFT was shown in the present embodiment mode as an example using a top gate TFT, a bottom gate TFT (typically a reverse stagger TFT) may also be used. The present invention is characterized by the film deposition method of the organic EL element, and the structure of the TFT to be arranged in the pixel is not limited.

[0077]

[Embodiments of the Invention]

[Embodiment 1]

The embodiments of the present invention are described using Figs. 4(A) to 6(C). A method of simultaneous manufacture of a pixel portion and TFTs of a driver circuit portion formed on the periphery of the pixel portion is described here. Note that in order to simplify the description, a CMOS circuit that is a basic circuit is illustrated as the driver circuits.

[0078]

First, as shown in Fig. 4(A), a base film 301 is formed to have a thickness of

300 nm on a glass substrate 300. A silicon nitride oxide film is laminated as the base film 301 in the present embodiment. At this point, it is appropriate to set the nitrogen concentration at between 10 and 25 wt% in the film contacting the glass substrate 300. In addition, it is effective that the base film 301 has a thermal radiation effect, and a DLC (diamond-like carbon) film may also be provided.

[0079]

Next, an amorphous silicon film (not shown in the figures) is formed with a thickness of 50 nm on the base film 301 by a known deposition method. Note that it is not necessary to limit to the amorphous silicon film, and another film may be formed provided that it is a semiconductor film containing an amorphous structure (including a microcrystalline semiconductor film). In addition, a compound semiconductor film containing an amorphous structure, such as an amorphous silicon germanium film, may also be used. Further, the film thickness may be made from 20 to 100 nm.

[0080]

The amorphous silicon film is then crystallized by a known technique, and then a crystalline silicon film (also referred to as a polycrystalline silicon film or a polysilicon film) 302 is formed. Thermal crystallization using an electric furnace, laser annealing crystallization using a laser light, and lamp annealing crystallization using an infrared lamp exist as known crystallization methods. Crystallization is performed in the present embodiment using an excimer laser light, which uses XeCl gas.

[0081]

Note that pulse emission excimer laser light formed into a linear shape is used in the present embodiment, however, a rectangular shape may be used. Further,

continuous emission argon laser light and continuous emission excimer laser light can also be used.

[0082]

In the present embodiment, although the crystalline silicon film is used as the active layer of the TFT, it is also possible to use an amorphous silicon film.

[0083]

Note that it is effective to form the active layer of the switching TFT, in which there is a necessity to reduce the off current, by the amorphous silicon film, and to form the active layer of the current control TFT by the crystalline silicon film. Electric current flows with difficulty in the amorphous silicon film since the carrier mobility is low, and the off current does not easily flow. In other words, the advantage of both the amorphous silicon film through which current does not flow easily, and the crystalline silicon film through which current easily flows can be employed efficiently.

[0084]

Next, as shown in Fig. 4(B), a protective film 303 with a silicon oxide film having a thickness of 130 nm is formed on the crystalline silicon film 302. This thickness may be chosen within the range of 100 to 200 nm (preferably between 130 and 170 nm). Furthermore, other films may also be used providing that they are insulating films containing silicon. The protective film 303 is provided so that the crystalline silicon film is not directly exposed to plasma during addition of an impurity, and so that delicate concentration control of the impurity becomes possible.

[0085]

Resist masks 304a and 304b are then formed on the protective film 303, and an impurity element, which imparts n-type conductivity (hereafter referred to as an n-type

impurity element), is added through the protective film 303. Note that elements belonging to the periodic table group 15 are generally used as the n-type impurity element, and typically phosphorous or arsenic can be used. Note that a plasma doping method is used, in which phosphine (PH_3) is plasma activated without separation of mass, and phosphorous is added at a concentration of $1x10^{18}$ atoms/cm^3 in the present embodiment. An ion implantation method, in which separation of mass is performed, may also be used, of course.

[0086]

The dose amount is regulated so that the n-type impurity element is contained in n-type impurity regions 305 and 306, thus formed by this process, at a concentration of $2x10^{16}$ to $5x10^{19}$ atoms/cm^3 (typically, between $5x10^{17}$ and $5x10^{18}$ atoms/cm^3).

[0087]

Next, as shown in Fig. 4(C), the protective film 303 is removed, and an activation of the added n-type impurity elements is performed. A known technique of activation may be used as the means of activation, however, activation is done by irradiation of excimer laser light in the present embodiment. As a matter of course, a pulse emission excimer laser and a continuous emission excimer laser may be used, and it is not necessary to place any limits on the use of excimer laser light. The purpose is the activation of the added impurity element, and it is preferable that irradiation be performed at an energy level at which the crystalline silicon film does not melt. Note that the laser irradiation may also be performed with the protective film 303 in place.

[0088]

The activation by heat treatment (furnace annealing) may also be used in combination with activation of the impurity element by laser light. When activation is

performed by heat treatment, considering the heat resistance of the substrate, it is appropriate to perform heat treatment approximately 450°C to 550°C.

[0089]

A boundary portion (connecting portion) with end portions of the n-type impurity regions 305 and 306, namely regions, in which the n-type impurity element is not added, on the periphery of the n-type impurity regions 305 and 306, is delineated by this process. This means that, at the point when the TFTs are later completed, extremely favorable connecting portion can be formed between LDD regions and channel forming regions.

[0090]

Next, unnecessary portions of the crystalline silicon film are removed as shown in Fig. 4(D) and island shape semiconductor films (hereafter referred to as active layers) 307 to 310 are formed.

[0091]

Then, as shown in Fig. 4(E), a gate insulating film 311 is formed, covering the active layers 307 to 310. An insulating film containing silicon and with a thickness of 10 to 200 nm, preferably between 50 and 150 nm, may be used as the gate insulating film 311. A single layer structure or a laminated structure may be used. A silicon nitride oxide film with 110 nm thickness is used in the present embodiment.

[0092]

Thereafter, a conductive film having a thickness of 200 to 400 nm is formed and patterned to form gate electrodes 312 to 316. In the present embodiment, the gate electrodes and wirings (hereinafter referred to as the gate wirings) electrically connected to the gate electrodes for providing conductive paths are formed of different materials

from each other. More specifically, the gate wirings are made of a material having a lower resistivity than the gate electrodes. Thus, a material enabling fine processing is used for the gate electrodes, while the gate wirings are formed of a material that can provide a smaller wiring resistance but is not suitable for fine processing. It is of course possible to form the gate electrodes and the gate wirings with the same material.

[0093]

Although the gate electrode may be made of a single-layered conductive film, it is preferable to form a lamination film with two, three or more layers for the gate electrode if necessary. Any known conductive materials can be used for the gate electrode. It should be noted, however, that it is preferable to use such a material that enables fine processing, and more specifically, a material that can be patterned with a line width of 2 μm or less.

[0094]

Typically, it is possible to use a film made of an element selected from tantalum (Ta), titanium (Ti), molybdenum (Mo), tungsten (W), chromium (Cr), and silicon (Si), a nitride film of the above element (typically a tantalum nitride film, tungsten nitride film, or titanium nitride film), an alloy film of combination of the above elements (typically Mo-W alloy or Mo-Ta alloy), or a silicide film of the above elements (typically a tungsten silicide film or titanium silicide film). As a matter of course, the films may be used as a single layer or a laminate layer.

[0095]

In the present embodiment, a laminated film of a tungsten nitride (WN) film having a thickness of 30 nm and a tungsten (W) film having a thickness of 370 nm is used. This may be formed by sputtering. When an inert gas of Xe, Ne or the like is

added as a sputtering gas, film peeling due to stress can be prevented.

[0096]

The gate electrodes 313 and 316 are formed at this time so as to overlap with a portion of the n-type impurity regions 305 and 306, respectively, with interposed the gate insulating film 311 therebetween. This overlapping portion later becomes an LDD region overlapping the gate electrode.

[0097]

Next, an n-type impurity element (phosphorous is used in the present embodiment) is added in a self-aligning manner with the gate electrodes 312 to 316 as masks, as shown in Fig. 5(A). The addition is regulated so that phosphorous is added to impurity regions 317 to 323 thus formed at a concentration of 1/10 to 1/2 that of the impurity regions 305 and 306 (typically between 1/3 and 1/4). Specifically, a concentration of $1x10^{16}$ to $5x10^{18}$ atoms/cm^3 (typically, $3x10^{17}$ to $3x10^{18}$ atoms/cm^3) is preferable.

[0098]

Resist masks 324a to 324c are formed next, with a shape covering the gate electrodes and the like as shown in Fig. 5(B), and an n-type impurity element (phosphorous is used in the present embodiment) is added to form impurity regions 325 to 331 containing phosphorous at high concentration. Ion doping using phosphine (PH_3) is also performed here, and is regulated so that the phosphorous concentration of these regions is from $1x10^{20}$ to $1x10^{21}$ atoms/cm^3 (typically, between $2x10^{20}$ and $5x10^{21}$ atoms/cm^3).

[0099]

A source region or a drain region of the n-channel TFT is formed by this

process, and in the switching TFT, a portion of the n-type impurity regions 320 to 322 formed by the process of Fig. 5(A) is remained. These remaining regions correspond to the LDD regions 15a to 15d of the switching TFT in Fig. 2.

[0100]

Next, as shown in Fig. 5(C), the resist masks 324a to 324c are removed, and a new resist mask 332 is formed. A p-type impurity element (boron is used in the present embodiment) is then added to form impurity regions 333 and 334 containing boron at high concentration. Boron is added here to form the impurity regions 333 and 334 at a concentration of $3x10^{20}$ to $3x10^{21}$ atoms/cm^3 (typically, between $5x10^{20}$ and $1x10^{21}$ atoms/cm^3) by ion doping using diborane (B_2H_6).

[0101]

Note that phosphorous has already been added to the impurity regions 333 and 334 at a concentration of $1x10^{20}$ to $1x10^{21}$ atoms/cm^3, but boron is added here at a concentration of at least 3 times that of the phosphorous. Therefore, the n-type impurity regions already formed completely invert to p-type, and function as p-type impurity regions.

[0102]

Next, after removing the resist mask 332, the n-type or p-type impurity elements added to the active layer at respective concentrations are activated. Furnace annealing, laser annealing, or lamp annealing methods can be used as a means of activation. In the present embodiment, heat treatment is performed for 4 hours at 550°C in a nitrogen atmosphere in an electric furnace.

[0103]

At this time, it is critical to eliminate oxygen from the atmosphere as much as

possible. This is because when even only a small amount of oxygen exists, an exposed surface of the gate electrode is oxidized, which results in an increased resistance and later makes it difficult to form an ohmic contact with the gate electrode. Accordingly, the oxygen concentration in the atmosphere for the activation process is set at 1 ppm or less, preferably at 0.1 ppm or less.

[0104]

After the activation process is completed, a gate wiring 335 having a thickness of 300 nm is formed. As a material for the gate wiring 335, a metal film containing aluminum (Al) or copper (Cu) as its main component (occupied 50 to 100% in the composition) can be used. The gate wiring 335 is arranged, as the gate wiring 211 shown in Figs. 3(A), so as to provide electrical connection for the gate electrodes 314 and 315 (corresponding to the gate electrodes 19a and 19b in Fig. 3(A)) of the switching TFT (Fig. 5(D)).

[0105]

The above-described structure can allow the wiring resistance of the gate wiring to be significantly reduced, and therefore, an image display region (pixel portion) with a large area can be formed. Thus, the pixel structure in accordance with the present embodiment is extremely advantageous for realizing an EL display device having a display screen with a diagonal size of 10 inches or larger (or 30 inches or larger).

[0106]

A first interlayer insulating film 336 is formed next, as shown in Fig. 6(A). As the first interlayer insulating film 336, a single layer insulating film containing silicon or a laminated film combined therein may be used. Further, a film thickness of

between 400 nm and 1.5 μm may be used. A laminated structure of a silicon oxide film with 800 nm thickness on a silicon nitride oxide film with 200 nm thickness is used in the present embodiment.

[0107]

In addition, heat treatment is performed for 1 to 12 hours at 300 to 450°C in an atmosphere containing between 3 and 100% hydrogen, and then hydrogenation is performed. This process is one of hydrogen termination of dangling bonds in the semiconductor film by hydrogen, which is thermally activated. Plasma hydrogenation (using hydrogen activated by plasma) may also be performed as another means of hydrogenation.

[0108]

Note that the hydrogenation processing may also be inserted during the formation of the first interlayer insulating film 336. Namely, hydrogen processing may be performed as above after forming the silicon nitride oxide film with 200 nm thickness, and then the remaining silicon oxide film with 800 nm thickness may be formed.

[0109]

Next, a contact hole is formed in the first interlayer insulating film 336, and source wirings 337 to 340 and drain wirings 341 to 343 are formed. In this embodiment, this electrode is made of a laminated film of three-layer structure in which a Ti film having a thickness of 100 nm, an aluminum film containing Ti and having a thickness of 300 nm, and a Ti film having a thickness of 150 nm are continuously formed by a sputtering method. As a matter course, other conductive films may be used.

[0110]

Next, a first passivation film 344 is formed with a thickness of 50 to 500 nm (typically between 200 and 300 nm). A silicon nitride oxide film with 300 nm thickness is used as the first passivation film 344 in the present embodiment. This may also be substituted by a silicon nitride film. Note that it is effective to perform plasma processing using a gas containing hydrogen such as H_2 or NH_3 before the formation of the silicon nitride oxide film. Hydrogen activated by this preprocess is supplied to the first interlayer insulating film 336, and the film quality of the first passivation film 344 is improved by performing heat treatment. At the same time, the hydrogen added to the first interlayer insulating film 336 diffuses to the lower side, and the active layers can be hydrogenated effectively.

[0111]

Next, as shown in Fig. 6(B), a second interlayer insulating film 345 made of organic resin is formed. As the organic resin, polyimide, polyamide, acryl, BCB (benzocyclobutene) or the like can be used. Especially, since the second interlayer insulating film 345 is primarily used for leveling, acryl excellent in leveling properties is preferable. In the present embodiment, an acrylic film is formed to have a sufficient thickness to level a stepped portion formed by TFTs. It is appropriate that the thickness is made 1 to 5 μm (more preferably, 2 to 4 μm).

[0112]

Thereafter, a contact hole is formed in the second interlayer insulating film 345 and the first passivation film 344 to reach the drain wiring 343, and then a pixel electrode 346 is formed. In the present embodiment, an aluminum alloy film (an aluminum film containing titanium of 1 wt%) having a thickness of 300 nm is formed as

the pixel electrode 346.

[0113]

Next, as shown in Fig. 6(C), a bank 347 made of resin material is formed. The bank 347 may be formed by patterning an acrylic film or polyimide film with 1 to 2 μm thicknesses. As shown in Fig. 3, the bank 347 is formed as a stripe shape between pixels. Although the bank 347 is formed along the source wiring 339 in the present embodiment, the bank 347 may also be formed along the gate wiring 336.

[0114]

A light emitting layer 348 is next formed by the film deposition process employing the thin film deposition apparatus described with reference to Fig. 1. Specifically, an organic EL material that becomes the light emitting layer 348 is dissolved in a solvent such as chloroform, dichloromethane, xylene, toluene, and tetrahydrofuran, and is then applied. Thereafter, heat treatment is performed to volatilize the solvent. A film (light emitting layer) made of the organic EL material is thus formed.

[0115]

It is to be noted that only one pixel is illustrated in the present embodiment. However, a light emitting layer that emits red color light, a light emitting layer that emits green color light, and a light emitting layer that emits blue color light are all formed at the same time at this point. In the present embodiment, a cyano-polyphenylene vinylene for the light emitting layer that emits red color light, a polyphenylene vinylene for the light emitting layer that emits green color light, and a polyalkylphenylene for the light emitting layer that emits blue color light are formed with 50 nm thickness, respectively. In addition, 1.2-dichloromethane is used as a

solvent, and then volatilized by performing heat treatment on a hot plate at 80 to 150°C for 1 to 5 minutes.

[0116]

Next, a hole injection layer 349 is formed to have a thickness of 20 nm. Since the hole injection layer 349 may be provided commonly for all the pixels, it is appropriate to form the hole injection layer 349 by utilizing the spin coating method or the printing method. In the present embodiment, polythiophene (PEDOT) is applied as a solution, and heat treatment is performed on a hot plate at 100 to 150°C for 1 to 5 minutes to volatilize its moisture. In this case, the hole injection layer 349 can be formed without dissolving the light emitting layer 348 since polyphenylene vinylene or polyalkylphenylene is insoluble.

[0117]

It is to be noted that a low molecular organic EL material may be used as the hole injection layer 349. In this case, it is appropriate to form the hole injection layer by the evaporation method.

[0118]

A two-layered structure made of the light emitting layer and the hole injection layer is formed in the present embodiment. However, other layers such as a hole transporting layer, an electron injection layer, and an electron transporting layer may also be provided. Examples of various combinations of such lamination structures of layers have been reported, and any structures may be used for the present invention.

[0119]

After the formation of the light emitting layer 348 and the hole injection layer 349, an anode 350 made of a transparent conductive film is formed to have a thickness

of 120 nm. Indium oxide, which is doped with 10 to 20 wt% of zinc oxide, is used for the transparent conductive film in the present embodiment. It is preferable to form the films by evaporation at room temperature as a deposition method so that the light emitting layer 348 and the hole injection layer 349 are not deteriorated.

[0120]

A second passivation film 351 made of a silicon nitride oxide film is formed to have a thickness of 300 nm by plasma CVD after the formation of the anode 350. At this point, it is also necessary to pay attention to the film deposition temperature. The remote plasma CVD may be employed to lower the film deposition temperature.

[0121]

An active matrix substrate having a structure as shown in Fig. 6(C) is thus completed. Note that after the formation of the bank 347, it is effective to use the thin film deposition apparatus of the multi-chamber method (or the in-line method) for the process of forming the films until the formation of the passivation film 351, in succession and without exposure to the atmosphere.

[0122]

In the active matrix substrate of the present embodiment, TFTs having optimal structures are arranged not only in the pixel portion but also in the driver circuit portion, thereby indicating an extremely high reliability and increasing its operation performance.

[0123]

First, a TFT having a structure to decrease hot carrier injection so as not to drop the operation speed thereof as much as possible is used as an n-channel TFT 205 of a CMOS circuit forming a driver circuit portion. Note that the driver circuit here

includes a shift register, a buffer, a level shifter, a sampling circuit (sample and hold circuit) and the like. In the case where digital driving is made, a signal conversion circuit such as a D/A converter can also be included.

[0124]

In the case of the present embodiment, as shown in Fig. 6(C), an active layer of the n-channel TFT 205 is composed of a source region 355, a drain region 356, an LDD region 357, and a channel forming region 358. The LDD region 357 overlaps with the gate electrode 313 with the gate insulating film interposed therebetween.

[0125]

Consideration not to drop the operation speed is the reason why the LDD region is formed at only the drain region side. In this n-channel TFT 205, it is not necessary to pay too much attention to an OFF current value, rather, it is better to give importance to an operation speed. Thus, it is desirable that the LDD region 357 is made to completely overlap with the gate electrode to decrease a resistance component to a minimum. That is, it is preferable to remove the so-called offset.

[0126]

Furthermore, deterioration of the p-channel TFT 206 in the CMOS circuit due to the injection of hot carriers is almost negligible, and thus, it is not necessary to provide any LDD region. It is of course possible to provide the LDD region, similarly for the n-channel TFT 205, to exhibit countermeasure against the hot carriers.

[0127]

Note that, among the driver circuits, the sampling circuit is somewhere unique compared to the other circuits, in which a large electric current flows in both directions in the channel forming region. Namely, the roles of the source region and the drain

region are interchanged. In addition, it is necessary to control the value of the off current to be as small as possible, and with that in mind, it is preferable to arrange a TFT having functions, which are on an intermediate level between the switching TFT and the current control TFT in the sampling circuit.

[0128]

Accordingly, in the n-channel TFT for forming the sampling circuit, it is desirable to arrange the TFTs having the structure as shown in Fig. 10. As illustrated in Fig. 9, portions of the LDD regions 901a and 901b overlap with the gate electrode 903 with interposed the gate insulating film 902 therebetween. The advantages by this structure have been already described with respect to the current control TFT 202. In the case of the sampling circuit, the point of disposing the channel forming region 904 that is interposed is different.

[0129]

Noted that, in practice, after completing up through Fig. 6(C), it is preferable to, additionally, perform packaging (sealing) by using a highly airtight protective film (such as a laminate film or an ultraviolet cured resin film) which has little gas leakage or a translucence sealing material, so that there is no exposure to the atmosphere. By making the inside of the sealing material an inert environment, and by placing a hygroscopic agent (for example, barium oxide) within the sealing material, the reliability of the EL element is increased.

[0130]

Furthermore, after airtightness is increased by a processing such as packaging, connectors (flexible print circuits: FPC) are attached to connect terminals pulled out from the elements or circuits formed on the substrate to external signal terminals, and

then, the semiconductor device is completed as a product. The state of being shipped is referred to as an EL display device (or EL module) in the present specification.

[0131]

Here, the structure of the active matrix EL display device of this embodiment will be described with reference to a perspective view of Fig. 7. The active matrix EL display device of this embodiment is constituted by a pixel portion 702, a gate side driver circuit 703, and a source side driver circuit 704 formed on a glass substrate 701. A switching TFT 705 of a pixel portion is an n-channel TFT, and is disposed at an intersection point of a gate wiring 706 connected to the gate side driver circuit 703 and a source wiring 707 connected to the source side driver circuit 704. The drain of the switching TFT 705 is connected to the gate of a current control TFT 708.

[0132]

In addition, the source side of the current control TFT 706 is connected to a current supply line 709. A ground electric potential (earth electric potential) is imparted to the current supply line 709 in the structure such as the present embodiment. Further, an EL element 710 is connected to the drain of the current control TFT 708. A predetermined voltage (between 3 and 12 V, preferably between 3 and 5 V) is applied to the anode of the EL element 710.

[0133]

Connection wirings 712 and 713 for transmitting signals to the driver circuit portion and a connection wiring 714 connected to the current supply line 709 are provided in an FPC 711 as an external input/output terminal.

[0134]

Fig. 8 shows an example of the circuit structure of the EL display device shown

in Fig. 7. The EL display device of the present embodiment is provided with a source side driver circuit 801, a gate side driver circuit (A) 807, a gate side driver circuit (B) 811 and a pixel portion 806. Note that, throughout the present specification, the driver circuit portion is the generic name for the source side driver circuit and the gate side driver circuits.

[0135]

The source side driver circuit 801 is provided with a shift register 802, a level shifter 803, a buffer 804, and a sampling circuit (sample and hold circuit) 805. The gate side driver circuit (A) 807 is provided with a shift register 808, a level shifter 809, and a buffer 810. The gate side driver circuit (B) 811 also has the same structure.

[0136]

Here, the shift registers 802 and 808 have driving voltages of 5 to 16 V (typically 10 V), and the structure indicated by 205 in Fig. 6(C) is suitable for an n-channel TFT used in a CMOS circuit forming the circuit.

[0137]

Besides, for each of the level shifters 803 and 809 and the buffers 804 and 810, similarly to the shift register, the CMOS circuit including the n-channel TFT 205 of Fig. 6(C) is suitable. Note that it is effective to make a gate wiring a multi-gate structure such as a double gate structure or a triple gate structure in improving reliability of each circuit.

[0138]

Besides, since the source region and the drain region are inverted and it is necessary to decrease an OFF current value, a CMOS circuit including the n-channel TFT 208 of Fig. 10 is suitable for the sampling circuit 805.

[0139]

The pixel portion 806 is disposed with pixels having the structure shown in Fig. 2.

[0140]

The foregoing structure can be easily realized by manufacturing TFTs in accordance with the manufacturing processes shown in Figs. 4(A) to 6(C). In this embodiment, only the structure of the pixel portion and the driver circuit portion is shown. However, if the manufacturing processes of this embodiment are employed, it is possible to form a logical circuit other than the driver circuit such as a signal dividing circuit, a D/A converter circuit, an operational amplifier circuit, a γ-correction circuit, on the same substrate. Further, it is considered that a memory portion, a microprocessor, or the like can be formed.

[0141]

Furthermore, the EL module, containing the sealing material, of the present embodiment is described with using Figs. 11(A) and (B). Noted that, when necessary, the symbols used in Figs. 7 and 8 are cited.

[0142]

Fig. 11(A) is a diagram showing the top view of a state in which the state shown in Fig. 7 is provided with a sealing structure. Indicated by dotted lines, reference numeral 702 denotes a pixel portion, 703 denotes a gate side driver circuit, and 704 denotes a source side driver circuit. The sealing structure of the present invention is a structure in which a filling material (not shown in the figure), a cover material 1101, a seal material (not shown in the figure), and a frame material 1102 are provided to the state shown in Fig. 7.

[0143]

Here, the cross-sectional view taken along line A-A' of Fig. 11(A) is shown in Fig. 11(B). It is to be noted that the same reference numerals are used for the same components in Figs. 11(A) and 11(B).

[0144]

As shown in Fig. 11(B), the pixel portion 702 and the gate side driver circuit 703 are formed on the substrate 701. The pixel portion 702 is formed of a plurality of pixels containing the current control TFT 202 and the pixel electrode 346 that is electrically connected to the current control TFT 202. Further, the gate side driver circuit 703 is formed by using a CMOS circuit that is a complementary combination of the n-channel TFT 205 and the p-channel TFT 206.

[0145]

The pixel electrode 346 functions as the cathode of the EL element. In addition, the bank 347 is formed on both ends of the pixel electrode 346, and the light emitting layer 348 and the hole injection layer 349 are formed on the inner side of the bank 347. The anode 350 of the EL element and the second passivation film 351 are further formed on the top. As mentioned in the embodiment mode of the present invention, the EL element may of course have a reverse structure with the pixel electrode as the anode.

[0146]

In the case of the present embodiment, the anode 350 also functions as a common wiring to all the pixels, and is electrically connected to the FPC 711 through the connection wiring 712. Furthermore, all the elements contained in the pixel portion 702 and the gate side driver circuit 703 are covered with the second passivation

film 351. The second passivation film 351 may be omitted. However, it is preferable to provide the second passivation film 351 to shield the respective elements from the outside.

[0147]

Next, a filling material 1103 is provided so as to cover the EL element. The filling material 1103 also functions as an adhesive for attaching the cover material 1101. As the filling material 1103, PVC (polyvinyl chloride), an epoxy resin, a silicon resin, PVB (polyvinyl butyral) or EVA (ethylene vinyl acetate) can be used. It is preferable to place a drying agent (not shown in the figure) inside the filling material 1103 because the hygroscopic effect can be maintained. At this point, the drying agent may be an agent doped into the filling material, or an agent enclosed in the filling material. However, a filling material having transmissivity is used in the case of the present embodiment, to thereby emitting light from the side of the filling material 1103.

[0148]

Further, in the present embodiment, a glass plate, , an FRP (Fiberglass-Reinforced Plastics) plate, PVF (polyvinyl fluoride) film, a mylar film, a polyester film, or an acrylic film can be used as the cover material 1101. In the case of the present embodiment, similar to the filling material, the cover material 1101 must be made of a transmissive material. Note that it is effective to dope a drying agent, such as barium oxide, into the filling material 1103 in advance.

[0149]

After using the filling material 1103 to attaching the cover material 1101, the frame material 1102 is next attached so as to cover a side surface (the exposed surface) of the filling material 1103. The frame material 1102 is attached by the seal material

(functioning as an adhesive) 1104. At this point, it is preferable to use a light cured resin as the seal material 1104. However, a thermally cured resin may be used as long as the heat resistance of the EL layer is acceptable. Note that it is desirable to use a material through which oxygen and moisture do not penetrate as much as possible, as the seal material 1104. In addition, a drying agent may be doped into the seal material 1104.

[0150]

The EL element is thus sealed into the filling material 1103 by using the above procedure, to thereby completely cutting off the EL element from the external atmosphere and to prevent the penetration of substances such as moisture and oxygen from the outside that stimulate the deterioration of the EL element due to the oxidation of the EL layer. Accordingly, a highly reliable EL display device can be manufactured.

[0151]

[Embodiment 2]

An example of simultaneously forming three types of stripe shape light emitting layers that emit red, green, and blue color lights, in a lengthwise direction or a lateral direction, was shown in Embodiment 1. In the present embodiment, an example of forming a strip shape light emitting layer that is divided into a plurality in a longitudinal direction is shown.

[0152]

As shown in Fig. 12(A), the pixel portion 111, the source side driver circuit 112, and the gate side driver circuit 113 are all formed of TFTs on the substrate 110. The pixel portion 111 is partitioned into matrix by a bank 1201. In the case of the present embodiment, a plurality of pixels 1203 is arranged within one of the squares

1202 partitioned by the bank 1201 as shown in Fig. 12(B). However, the number of pixels is not limited.

[0153]

In such a state, the film deposition process of an organic EL material for functioning as a light emitting layer is carried out using the thin film deposition apparatus of Fig. 1. Even in this case, the red application liquid 114a, the green application liquid 114b, and the blue application liquid 114c are separately applied to by the head portion 115 at the same time.

[0154]

The present embodiment is characterized by the fact that the application liquids 114a to 114c can be applied separately to the above stated respective squares 1202. In other words, the application liquids of each color, red, green, and blue, can only be applied separately in a stripe shape in the method of Fig.1, whereas in the present embodiment, the colors can be freely arranged in each square. Therefore, as shown in Fig. 12(A), it is possible to arrange a color of the application liquid to be applied to an optional square in a manner so that a whole row (or column) is being shifted.

[0155]

Further, in the square 1202, the provision of one pixel is also possible, and in this case, the pixel structure which is generally referred to as delta arrangement (a pixel structure in which pixels corresponding to the respective RGB are arranged so as to always form a triangle) can be adopted.

[0156]

Operations imparted to the head portion 115 for the purpose of implementing the present embodiment are as follows. First, the head portion 115 is moved to the

direction indicated by the arrow a, to thereby completely soaking the inside of three squares (the respective squares corresponding to the colors red, green, and blue) with the application liquids. After completing this operation, the head portion 115 is moved to the direction indicated by the arrow b, to thereby applying the application liquid to the next three squares. The application liquids are applied to the pixel portion by repeating this operation. Thereafter,. the solvent is volatilized by heat treatment to form an organic EL material.

[0157]

In an example described in the conventional ink-jet method, the organic EL material formed for the application of liquid drops becomes circular. Therefore, it is difficult to cover the entire long and narrow pixel. In particular, in the case of Embodiment 1 in which the entire pixel functions as a light emitting region, the entire pixel needs to be covered by the organic EL material. On the other hand, the present embodiment has a merit in that the squares can be completely filled with the application liquids by moving the head portion 115 in the direction indicated by the arrow a.

[0158]

Noted that the present embodiment can be used for the manufacturing the EL display device described in Embodiment 1. The bank 1201 may be formed into a matrix shape by patterning, and the operations of the head portion 115 may be electrically controlled.

[0159]

[Embodiment 3]

A case of employing the present invention in a passive type (simple matrix type) EL display device is described in the present embodiment with reference to Fig.

13. In Fig. 13, reference numeral 1301 denotes a plastic substrate and 1302 denotes a cathode made of an aluminum alloy film. The cathode 1302 is formed by the evaporation method in the present embodiment. Note that although not shown in Fig. 13, a plural number of lines of cathodes are arranged in a stripe shape, in a perpendicular direction on a defined space.

[0160]

Further, a bank 1303 is formed so as to fill up the spaces between the cathodes 1302 arranged in stripes. The bank 1303 is formed along the cathodes 1302 in a perpendicular direction on the defined space.

[0161]

Subsequently, light emitting layers 1304a to 1304c made of an organic polymer EL material are formed by the film deposition method employing the thin film deposition apparatus of Fig. 1. As a matter of course, reference numeral 1304a is a light emitting layer that emits red color, 1304b is a light emitting layer that emits green color, and 1304c is a light emitting layer that emits blue color. An organic EL material similar to that of Embodiment 1 may be used. Since these light emitting layers are formed along the grooves, which are formed by the bank 1302, these layers are arranged in a stripe shape, in a perpendicular direction on the defined space.

[0162]

Thereafter, a hole injection layer 1305 which is common for all the pixels is formed by the spin coating method or the printing method. The hole injection layer may also be similar to the one of Embodiment 1. In addition, an anode 1306 made of a transparent conductive film is formed on the hole injection layer 1305. In the present embodiment, a compound of indium oxide and zinc oxide formed by the evaporation

method is formed as the transparent conductive film. Note that although not shown in Fig. 13, the parallel direction of a plural number of lines of anodes on the defined space is the longitudinal direction, and that the anodes are arranged in a stripe shape so as to intersect with the cathodes 1302. Furthermore, a wiring, not shown in the drawing, is drawn to a portion where an FPC will be attached later so that a predetermined voltage can be applied to the anodes 1306.

[0163]

Further, after the formation of the anode 1306, a silicon nitride film as a passivation film, not shown in the drawing, may be provided.

[0164]

An EL element is thus formed on the substrate 1301. Note that since a lower side electrode is a light-shielding cathode, light generated by the light emitting layers 1304a to 1304c is irradiated to an upper surface (a surface opposite the substrate 1301). However, the lower side electrode can be transparent anode by reversing the structure of the EL element. In that case, light generated by the light emitting layers 1304a to 1304c is irradiated to a lower surface (the substrate 1301).

[0165]

A plastic plate is prepared as a cover material 1307. A light-shielding film or a color filter may be formed on the surface when necessary. In the structure of the present embodiment, the cover material 1307 is transmissive since light emitted from the EL element penetrates the cover material 1307 and enters the eyes of an observer. A plastic plate is used in the present embodiment, however, a glass plate and a transparent substrate (or a transparent film) such as a PVF film may be used. As a matter of course, as described previously, in the case of reversing the structure of the EL

element, the cover material may have light shielding characteristics. Hence, a ceramic substrate and the like can be used.

[0166]

When the cover material 1307 is thus prepared, the cover material 1307 is then attached by a filling material 1308 that is doped with a barium oxide as a drying agent (not shown in the figure). Then, frame material 1310 is attached by using a seal material 1309 made of an ultraviolet cured resin. A stainless material is used as the frame material 1310 in the present embodiment. Finally, an FPC 1312 is attached with conductive paste 1311, thereby completing a passive type EL display device.

[0167]

[Embodiment 4]

When the active matrix EL display device of the present invention is seen from the direction of Fig. 11(A), the rows of pixel may be formed in a lengthwise direction or lateral direction. In other words, the arrangement of the pixels becomes such as that of Fig. 14(A) in the case of forming the rows of pixels in the lengthwise direction. On the other hand, the arrangement of the pixels becomes such as that of Fig. 14(B) in the case of forming the rows of pixels in the lateral direction.

[0168]

In Fig. 14(A), reference numeral 1401 denotes a bank formed into a stripe shape in the lengthwise direction, 1402a denotes an EL layer that emits a red color light, and 1402b denotes an EL layer that emits green color light. An EL layer that emits blue color light (not shown in the figure) is, of course, formed next to the EL layer 1402b that emits green color light. It is to be noted that in the upper direction of a source wiring through an insulating film, the bank 1401 is formed along the source

wiring.

[0169]

The EL layer referred to here indicates a layer made of an organic EL material that contributes to the luminescence of layers such as a light emitting layer, a charge injection layer, and a charge transporting layer. There are cases of forming a light emitting layer as a single layer. However, in the case of forming a laminate layer of a hole injection layer and a light emitting layer, for example, this laminate film is called an EL layer.

[0170]

At this point, it is desirable that a mutual distance (D) of pixels 1403 indicated by the dotted line is set to be 5 times or greater (preferably 10 times or greater) than the film thickness (t) of the EL layer. The reason for this resides in that if $D < 5t$, the problem of cross talk may occur between pixels. Note that if the distance (D) between pixels is also too far apart, high definition images cannot be obtained. Therefore, it is preferable that the distance (D) be $5t < D < 50t$ (preferably $10t < D < 35t$).

[0171]

Further, in Fig. 14(B), reference numeral 1404 denotes a bank formed into a stripe shape in the lateral direction, 1405a denotes an EL layer that emits red color light, 1405b denotes an EL layer that emits green color light. 1405c denotes an EL layer that emits green color light. It is to be noted that in the upper direction of a gate wiring through an insulating film, the bank 1404 is formed along the gate wiring.

[0172]

In also this case, it is appropriate that a mutual distance (D) of pixels 1406 indicated by the dotted line is set to be 5 times or greater (preferably 10 times or

greater) than the film thickness (t) of the EL layer, and further it is preferable that the distance (D) be $5t < D < 50t$ (preferably $10t < D < 35t$).

[0173]

Note that the constitution of the present embodiment may be implemented by combining the present embodiment with any of the constitutions of Embodiments 1 to 3. By regulating the relationship between the distance of the pixels and the film thickness of the EL layer as in the present embodiment, it becomes possible to display high definition images without cross talk.

[0174]

[Embodiment 5]

An example of forming all the light emitting layers, the light emitting layer that emits red color light, the light emitting layer that emits green color light, and the light emitting layer that emits blue color light, by using the thin film deposition apparatus of Fig. 1 was illustrated in Embodiment 1. However, the light emitting layer formed by using the thin film deposition apparatus of Fig. 1 may be a layer for at least one of the colors, red, green, and blue.

[0175]

That is, in Fig. 1(B), it is possible that the nozzle 116c (a nozzle for applying the blue light emitting layer application liquid) is omitted, and that the blue light emitting layer application liquid 114c is applied by other application means. An example of this is shown in Fig. 15.

[0176]

Fig. 15 is an example of a case in which the constitution of the present embodiment is employed in the passive type EL display device illustrated in

Embodiment 3. The basic structures are the same as those of the passive type EL display device shown in Fig. 13, and therefore only the reference numerals of different portions are changed and described.

[0177]

In Fig. 15, after forming the cathode 1302 on the substrate 1301, the light emitting layer 1304a that emits red color light and the light emitting layer 1304b that emits green color light are formed by using the thin film deposition apparatus of Fig. 1. Then, a light emitting layer 1501 that emits blue color light is formed thereon by the spin coating method, the printing method, or the evaporation method. In addition, the hole injection layer 1305 and the anode 1306 are formed.

[0178]

Thereafter, the filling material 1308, the cover material 1307, the seal material 1309, the frame material 1310, the conductive paste 1311, and the FPC 1312 are formed in accordance with the description of Embodiment 3, to thereby complete the passive type EL display device of Fig. 15.

[0179]

The present embodiment is characterized in that the light emitting layer 1304a that emits red color light, the light emitting layer 1304b that emits green color light, and the light emitting layer 1501 that emits blue color light are formed by different means. As a mater of course, the colors may be freely combined, and the light emitting layer that emits green color light may be formed by the spin coating method, the printing method, or the evaporation method instead of the above-mentioned light emitting layer that emits blue color light.

[0180]

In addition, the light emitting layer that emits green color light is formed by using the injection device of Fig. 1, and the light emitting layer that emits red color light and the light emitting layer that emits blue color light may be formed by the spin coating method, the printing method, or the evaporation method. Even in this case, the colors can be freely combined.

[0181]

According to the structure of the present embodiment, at least one of the red light emitting pixel, the green light emitting pixel, and the blue light emitting pixel has a structure that is a laminate layer of two different types of light emitting layers as the light emitting layer. In this case, either one of the two different types of light emitting layers emits one of the colors due to the mobility of energy. However, whichever color light will be emitted can be examined in advance. Thus, it is appropriate to design the structure so that the colors, red, green, and blue can be finally obtained.

[0182]

As an advantageous point of structuring the light emitting layer as a laminate layer, such as the one stated above, the point that the possibility of a short circuit caused by a pinhole becomes low can be cited. Since the light emitting layer is very thin, the occurrence of short circuit in the cathode and anode caused by the pinhole becomes a problem. However, the filling up of the pinhole is carried out by structuring a laminate layer, and therefore the possibility of a short circuit occurring can be greatly reduced. In such a meaning, it is effective to form the light emitting layer that is provided on the upper layer of the laminate structure by the evaporation method where it is difficult for pinholes to occur.

[0183]

Note that in the present embodiment, a description was made taking the passive type EL display device as an example. However, the active matrix EL display device may also be employed. Accordingly, it is possible to implement the constitution of the present embodiment by freely being combined with the constitution of any of Embodiments 1 to 4.

[0184]

[Embodiment 6]

An example of the head portion 115 in which 3 nozzles are attached thereto is shown in Fig. 1. However, the head portion may be further attached with 3 or more nozzles in correspondence with the plurality of rows of pixels, and an example of which is shown in Fig. 16. It is to be noted that the letters R, G, and B correspond to red, green, and blue respectively.

[0185]

Fig. 16 shows an example of collectively applying an organic EL material (strictly application liquid) to all the rows of pixels formed in the pixel portion. That is, the number of nozzles attached to a head portion 1601 is the same as the number of rows of pixels. By constructing such a structure, it becomes possible to apply the application liquid to the entire rows of pixels in one scan, thereby making a rapid increase in throughput.

[0186]

Further, the pixel portion is partitioned into a plurality of zones. A head portion provided with the same number of nozzles as the number of rows of pixels contained in each zone may be employed. In other words, if the pixel portion is partitioned into n number of zones, then the organic EL material (strictly application

liquid) can be applied to all the rows of pixels by scanning n number of times.

[0187]

Since there are actually cases where the size of the pixels is small, several tens of μm, then the width of a pixel row is also about several tens of μm. In such a case, the arrangement of the nozzles needs to be contrived because it is difficult to arrange the nozzles in one horizontal row.

[0188]

Fig. 17 shows an example in which the attachment positions of the nozzles to the head portion are altered. Fig. 17(A) is an example that nozzles 52a to 52c are formed on the head portion 51 while shifting their attachment positions diagonally. Note that reference numeral 52a denotes a nozzle for applying red light emitting layer application liquid, 52b denotes a nozzle for applying green light emitting layer application liquid, and 52c denotes a nozzle for applying blue light emitting layer application liquid. Further, each of the arrows corresponds to a pixel row.

[0189]

The nozzles 52a to 52c are then considered as one unit as indicated by reference numeral 53. Thus, the head portion is provided with one to several numbers of units. If there is one unit 53, then the organic EL material can be applied to 3 rows of pixels at the same time. This means that if there are n numbers of units, then the organic EL material can be applied to n numbers of 3 rows of pixels at the same time.

[0190]

By forming such a structure, the degree of freedom in the arrangement space of nozzles is raised, making it possible to implement the present invention in a high definition pixel portion without much difficulty. In addition, the head portion 51 of

Fig. 17(A) may be used in collectively processing all the rows of pixels in the pixel portion, or may be used in the case where the pixel portion is partitioned into a plurality of zones and the process of the rows of pixels is partitioned into several times.

[0191]

A head portion 54 shown in Fig. 17(B) is a modified version of Fig. 17(A). The head portion 54 is an example of a case of increasing the number of nozzles contained in one unit 55. In other words, 2 nozzles 56a for applying the red light emitting layer application liquid, 2 nozzles 56b for applying the green light emitting layer application liquid, and 2 nozzles 56c for applying the blue light emitting layer application liquid are contained in the unit 55. Hence, a total of 6 rows of pixels can be applied with the organic EL material at the same time by one unit 55.

[0192]

One to a plural number of the above-mentioned unit 55 can be provided in the present embodiment. If there is only one unit 55, then the organic EL material can be applied to 6 rows of pixels at the same time. If there are n numbers of unit 55, then the organic EL material can be applied to n numbers of 6 rows of pixels at the same time. As a matter of course, the number of nozzles provided in the unit 55 is not necessarily limited to 6, however, an additional number of nozzles may be provided.

[0193]

In the case of such structure, similarly to the case of Fig. 17(A), all the rows of pixels in the pixel portion can be collectively processed, or it is possible to partition the process into several times when the pixel portion is partitioned into a plurality of zones.

[0194]

In addition, a head portion such as a head portion 57 shown in Fig. 17(C) can

be used. In the head portion 57, a space for 3 rows of pixels is opened for provision of a nozzle 58a for applying the red light emitting layer application liquid, a nozzle 58b for applying the green light emitting layer application liquid, and a nozzle 58c for applying the blue light emitting layer application liquid.

[0195]

First, the head portion 57 is scanned once to apply the organic EL material to the rows of pixels. Next, the head portion 57 is shifted by 3 rows of pixel to the right and scanned again. Then the head portion is further shifted by 3 rows of pixels to the right and scanned again. Scanning is thus performed 3 times, whereby the organic EL material can be applied to the stripes lined in the order of red, green, and blue.

[0196]

Also in the case of such a structure, similarly to the case of Fig. 17(A), all the rows of pixels in the pixel portion can be collectively processed, or it is possible to partition the process into several times when the pixel portion is partitioned into a plurality of zones.

[0197]

Thus, in the thin film deposition apparatus of Fig. 1, by contriving the position of nozzles to be attached to the head portion, the present invention can also be implemented in a high definition pixel portion having very narrow pixel pitches (the distance between pixels). Furthermore, the throughput of the manufacturing process can be increased.

[0198]

Note that the constitution of the present embodiment can be implemented by freely being combined with the constitution of any of Embodiments 1 to 5.

[0199]

[Embodiment 7]

When the present invention is implemented to manufacture an active matrix EL display device, it is effective to use a silicon substrate (silicon wafer) as a substrate. In the case of using the silicon substrate as the substrate, a manufacturing technique of MOSFET utilized in the conventional IC, LSI or the like can be employed to manufacture a switching element and a current control element to be formed in the pixel portion, or a driver element to be formed in the driver circuit portion.

[0200]

The MOSFET can form circuits having extremely small variations, as there are achievements in the IC and the LSI. In particularly, it is effective for the active matrix EL display device of an analog driver performing gradation display by an electric current value.

[0201]

It is to be noted that the silicon substrate is not transmissive, and therefore the structure needs a structure so that light from the light emitting layer is irradiated to an opposite side of the substrate. The structure of the EL display device of the present embodiment is similar to that of Fig. 11. However, the point of difference is that the MOSFET is used instead of a TFT forming the pixel portion 702 and the driver circuit portion 703.

[0202]

[Embodiment 8]

An EL display device formed by implementing the present invention is self-light emitting type, and thus has superior visibility in bright locations in comparison

to a liquid crystal display device and furthermore, has wide viewing angle. Accordingly, the EL display device can be used as a display portion for various electronic devices. For example, it is appropriate to use the EL display device of the present invention as a display portion of an EL display (a display incorporating the EL display device in a frame body) having a diagonal equal to 30 inches or greater (typically equal to 40 inches or greater) for appreciation of TV broadcasts and the like by large screen.

[0207]

Noted that all displays exhibiting information such as a personal computer display, a TV broadcast reception display, or an advertisement display are included as the EL display. Further, the EL display device of the present invention can be used as a display portion of the other various electronics devices.

[0204]

A video camera, a digital camera; a goggle type display (head mounted display), a car navigation system, an audio reproducing device (such as a car audio system or an audio compo system), a laptop personal computer; a game equipment, a portable information terminal (such as a mobile computer, a mobile telephone, a mobile game equipment or an electronic book), and an image playback device provided with a recording medium (specifically, a device which performs playback of a recording medium and is provided with a display which can display those images, such as a digital video disk (DVD)) can be cited as examples of such electronics devices of the present invention. Since portable information terminals are often viewed from a diagonal direction, the widness of the viewing angle thereof is regarded as important. Thus, it is preferable that the EL display is employed. Examples of these electronics devices are

shown in Figs. 18 and 19.

[0205]

Fig. 18(A) is an EL display, including a frame body 2001, a support stand 2002, and a display portion 2003. The present invention can be used in the display portion 2003. Since the EL display is a self-light emitting type device without the need of a backlight, the display portion can be made thinner than a liquid crystal display device.

[0206]

Fig. 18(B) is a video camera, including a main body 2101, a display portion 2102, an audio input portion 2103, operation switches 2104, a battery 2105, and an image receiving portion 2106. The EL display device of the present invention can be used in the display portion 2102.

[0207]

Fig. 18(C) is a portion of a head fitting type EL display (right side), including a main body 2201, signal cables 2202, a head fixing band 2203, a display portion 2204, an optical system 2205, and an EL display device 2206. The present invention can be used in the EL display device 2206.

[0208]

Fig. 18(D) is an image playback device (specifically, a DVD playback device) provided with a recording medium, including a main body 2301, a recording medium (such as a DVD) 2302, operation switches 2303, a display portion (a) 2304, and a display portion (b) 2305. The display portion (a) mainly displays image information, and the image portion (b) mainly displays character information. The EL display device of the present invention can be used in the image portion (a) and in the image portion (b). Note that domestic game equipment is included as the image playback

device provided with a recording medium.

[0209]

Fig. 18(E) is a mobile (mobile) computer, including a main body 2401, a camera portion 2402, an image receiving portion 2403, an operation switch 2404, and a display portion 2405. The EL display device of the present invention can be used in the display portion 2405.

[0210]

Fig. 18(F) is a personal computer, including a main body 2501, a frame body 2502, a display portion 2503, and a keyboard 2504. The EL display device of the present invention can be used in the display portion 2503.

[0211]

Note that in the future, if the emission luminance of EL materials becomes higher, light including outputted images can be enlarged by lenses or the like. Then it will become possible to use the EL display device of the present invention in a front type or a rear type projector.

[0212]

The above electronic devices are becoming more often used to display information provided through an electronic transmission circuit such as the Internet or CATV (cable television), and in particular, opportunities for displaying animation information are increased. The response speed of EL materials is extremely high, and therefore the EL display device is favorable for performing animation display. However, the contours between pixels become hazy, whereby the entire animation also becomes hazy. Accordingly, it is extremely effective to use the EL display device of the present invention in the display portion of electronic equipment since the contours

between pixels are capable of clarifying.

[0213]

The emitting portion of the EL display device consumes power, and therefore it is preferable to display information so as to have the emitting portion become as small as possible. Therefore, when using the EL display device in a display portion that mainly displays character information, such as a portable information terminal, in particular, a portable telephone and an audio reproducing device, it is preferable to drive the EL display device by setting non-emitting portions as background and forming character information in emitting portions.

[0214]

Fig. 19(A) is a portable telephone, including a main body 2601, an audio output portion 2602, an audio input portion 2603, a display portion 2604, operation switches 2605, and an antenna 2606. The EL display device of the present invention can be used in the display portion 2604. Note that by displaying white characters in a black background in the display portion 2604, the power consumption of the portable telephone can be reduced.

[0215]

Fig. 19(B) is an audio reproducing device, specifically a car audio system, including a main body 2701, a display portion 2702, and operation switches 2703 and 2704. The EL display device of the present invention can be used in the display portion 2702. Furthermore, an audio reproducing device for a car is shown in the present embodiment, however, the audio reproducing device may also be used for a mobile type and a domestic type of audio reproducing device. Note that by displaying white characters in a black background in the display portion 2704, the power

consumption can be reduced. This is particularly effective in a mobile type audio reproducing device.

[0216]

As mentioned above, the range of applications of the present invention is thus extremely wide, and it is possible to apply the present invention to electronic devices in all fields. Furthermore, any constitution of the EL display device shown in Embodiments 1 to 7 may be employed in the electronic devices of the present embodiment.

[0217]

[Effect of the Invention]

Implementing the present invention makes it undoubtedly possible to perform film deposition of an organic EL material without the aviation curve problem, which occurs in the ink-jet method. That is, since a polymer organic EL material can be deposited as a film accurately without any problem of positional shift. Therefore, the production yield of an EL display device using a polymer organic EL material can be increased. Further, the organic EL material is applied not in the form of a "dot" as in the ink-jet method, but in the form of a "line", and therefore, a high throughput is attained.

[Brief Description of the Drawings]

[Fig. 1] diagrams showing an application process of an organic EL material of the present invention.

[Fig.2] a diagram showing the cross-sectional structure of a pixel portion.

[Fig. 3] diagrams showing the top structure and the configuration, respectively, of the pixel portion.

[Fig. 4] diagrams showing manufacturing processes of an EL display device.

[Fig.5] diagrams showing manufacturing processes of an EL display device.

[Fig. 6] diagrams showing manufacturing processes of an EL display device.

[Fig. 7] a diagram showing an external view of an EL display device.

[Fig. 8] a diagram showing the circuit block structure of an EL display device.

[Fig. 9] an enlarged diagram of the pixel portion.

[Fig. 10] a diagram showing the element structure of a sampling circuit of an EL display device.

[Fig.11] diagrams showing the cross-sectional structure of an active matrix EL display device.

[Fig. 12] diagrams showing an application process of an organic EL material of the present invention.

[Fig. 13] a diagram showing the cross-sectional structure of a passive type EL display device.

[Fig. 14] enlarged diagrams of the pixel portion.

[Fig. 15] a diagram showing a cross-sectional structure of a passive type EL display device.

[Fig. 16] a diagram showing an application process of an organic EL material of the present invention.

[Fig. 17] diagrams showing the arrangement of nozzles in the head portion.

[Fig. 18] diagrams showing specific examples of electronic equipment.

[Fig. 19] diagrams showing specific examples of electronic equipment.

[Document Name] Abstract

[Summary]

[Problem] A high throughput film deposition means for depositing an organic EL material made of polymer as a film accurately without any positional shift is provided.

[Solving Means] A pixel portion 111 is partitioned into a plurality of pixel rows by a bank 121, and a head portion 115 of a thin film deposition apparatus is scanned along a pixel row to thereby simultaneously apply a red light emitting layer application liquid 114a, a green light emitting layer application liquid 114b, and a blue light emitting layer application liquid 114c in stripes. Heat treatment is then performed to thereby form light emitting layers that emit each of the colors red, green, and blue.

[Selected drawing] Fig. 1